remote system must then imply that these causes propagate with infinite speed and hence we must accept the discontinuity this entails.

One of the interesting features of both Bell's original theorem and the result of Bancal *et al.* is that they rely on the philosophically slippery notion of 'free choice' of the experiment to be performed. Now what if we insist that our physical theory — simply to be compatible with free choice — must not let actions over here instantly change the real state of affairs over there? That is, regardless of whether we are able to receive the signal corresponding to the free choice of our remote friend or not, compatibility with the causal structure of special relativity suggests we should not let such influences occur at all. Otherwise if a purportedly free choice at A is correlated with a space-like separated event at B, then in some reference frame B happens before A and something that can be predicted in advance is not a free choice. Roger Colbeck and Renato Renner[2–4] have recently proved a powerful result, that under such assumptions no theory could predict the results of measurement outcomes any better than quantum theory does — any supposedly deeper theory of nature is forced into being exactly equivalent in terms of operational predictions to quantum theory.

The $v > c$ theories ruled out by Bancal *et al.* are theories that would not be compatible with the causal structure of special relativity, and — as the Colbeck and Renner argument shows — theories that are compatible with relativistic causal structure are constrained to be essentially quantum mechanical. But what are the causal structures that quantum theory is compatible with? In fact quantum theory treats events occurring sequentially at the same place very differently from events occurring simultaneously at different locations. Can these situations be treated more even-handedly, or could we even dispense with causal structure altogether? Matthew Leifer and Robert Spekkens have recently answered the first question in the affirmative in a paper[5] that represents significant progress on the Bayesian view of quantum theory most vigorously championed by Christopher Fuchs[6]. Ognyan Oreshkov and colleagues provide a tantalizing glimpse at the possibilities in the second direction[7]. They developed a framework for multipartite quantum correlations assuming only that experimenters in their local laboratories are free to perform arbitrary quantum operations. Remarkably, they find quantum correlations that are neither causally ordered nor in a probabilistic mixture of definite causal orders. These correlations are shown to enable a communication task that is impossible if a fixed background time is assumed.

Recently, Markus Müller and collaborators[8,9] derived the Hilbert space formalism of quantum theory from simple operational and information theoretic principles. They showed that three simple postulates — basically formulating the behaviour of a Stern–Gerlach device in abstract information-theoretic language — are sufficient to uniquely single out quantum theory and the three-dimensionality of space. This yields a rigorous theorem on the relation between space and probability, confirming earlier speculation by means of mathematical tools from quantum information theory.

I find it remarkable that the completely abstract tools and notions of information theory have something deep to say about the messy physical world in which I am flailing around. At such times I remember E.T. Jaynes' 1957 derivation[10] of the laws of classical statistical mechanics from the recently invented (at that time) information theory of Shannon. This first unifying step is, to my mind, one of the great achievements of physics in the past century. ❐

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ASTRONOMY

The great galaxy giveaway

Galaxies are dynamic and heterogeneous, and hence time-consuming to study using a traditional spectrometer. This is where the Calar Alto Legacy Integral Field Area (CALIFA) survey excels. Using an integral field spectrograph, the 3.5-metre telescope at the Calar Alto Observatory collects light from 350 specific points within each of 600 local galaxies. Thus, just one exposure produces detailed information from various parts of a given galaxy.

The first data release covers the 151 galaxies pictured. Each pixel contains spectral information about a galaxy's activity (red when star formation is minimal, blue when it's extensive) and content, where brightness indicates the number of stars.

MAY CHIAO